A Study of Variations in Soil and Water Chemistry of Selected Ponds at Brookhaven National Laboratory

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Abstract

Brookhaven National Laboratory (BNL), a 5,265 acre site, contains a variety of wetlands; included are coastal plain ponds, vernal pools, recharge basins, and streams. Wetland habitats in Pine Barrens communities serve important ecosystem functions, including providing critical habitat for the state endangered tiger salamander (*Ambystoma tigrinum*) and a number of other rare species. Survey techniques were used to gather information on soil and water chemistry of seven coastal plain ponds at BNL: four natural ponds (BP1, BP2, BP6, BP9), one man-modified pond (BP7), and two man-made ponds (BP13a, Meadow Marsh). Each pond was tracked using Global Positioning System (GPS) technology and mapped using ArcGIS. Five water samples were collected at each pond; nine soil samples were collected at five of the seven ponds. Water samples were analyzed for iron, sulfate, total chlorine, copper, aluminum, nitrate, phosphorus, tannin-lignin, suspended solids, hardness, total chromium, and molybdenum using HACH DREL/2000 and HACH CEL/890 water test kits. Soil samples were analyzed for pH, nitrate nitrogen, phosphorus, potassium, aluminum, ferric iron, magnesium, sulfate, calcium, and chloride using LaMotte soil test kits. Soil temperature, color, texture, structure, and consistency were also determined. A YSI 650 MDS meter with multi-probe was used to field-test water temperature, pH, dissolved oxygen, turbidity, and conductivity at each sample point. Water samples and soil extracts were also analyzed using an ICP-AES. The pH and temperature of the soil around the natural ponds was significantly lower than that of the anthropogenic ponds. The pH of the water from the natural ponds was significantly more acidic and the tannin-lignin content significantly higher than that of the anthropogenic ponds. We propose that these differences in the soil and water chemistry of the ponds can be explained by the nature of the surrounding vegetation. The presence of a tree canopy and dense shrub layer around the natural ponds reduces their exposure to solar radiation and increases the amount of leaf litter being added to the soil and water. The results of this study provide baseline data for monitoring pond health in the future and for assessing the suitability of ponds as breeding sites for tiger salamanders (*Ambystoma tigrinum*).

Introduction

Pine Barrens are a type of temperate coniferous forest found in southern New Jersey, Long Island, New York, and Cape Cod, Massachusetts [1]. Pine Barrens develop on soils that are nutrient poor and acidic, with a high percentage (80-96%) of well-drained sand [3]. Pine Barrens are maintained by periodic natural wildfires and without them their distinctive vegetation is replaced by hardwood forest and weedy species [1, 4]. Pitch pine (*Pinus rigida*) is the dominant tree species of the Pine Barrens. Pitch pine requires bare mineral soil for establishment from seed, is relatively shade-intolerant, and possesses adaptations to survive the fires that frequent the Pine Barrens [5]. Vernal ponds and coastal plain ponds play an important role in Pine Barrens communities: water storage, replenishment of the aquifer, nutrient retention and cycling, and they can be an important water source and refuge for resident and migrating wildlife [6, 7]. On Long Island, these ponds provide breeding habitat for frogs, toads, and salamanders, including the New York state endangered tiger salamander (*Ambystoma tigrinum*) [8, 9]. Although many studies have been carried out in the Central Pine Barrens, little is known about the soil and water chemistry of these critical breeding sites. In light of this a study was initiated to investigate several coastal plain ponds on BNL, both natural (fig. 1) and man-made or man-modified (fig. 2).

Fig 1. BP1: A natural pond

Fig 2. MM: A man-made pond

Methods and Materials

Seven ponds on Brookhaven National Laboratory were selected for sampling. They were designated BP1, BP2, BP6, BP7, BP9, BP13a, and Meadow Marsh (MM). BP1, BP2, BP6 and BP9 are natural ponds in a forested landscape; BP7, BP13a and MM are anthropogenic. A track of each pond was taken using an eTrex® Vista Cx Global Positioning System unit. These were downloaded into ArcGIS. Four water sampling points were marked on the north, south, east, and west sides of each pond; a fifth sampling point was established at the approximate center of the pond. A YSI 650 MDS meter with multi-probe was used to determine temperature, pH, dissolved oxygen, turbidity, and conductivity of the water. Water samples brought back to the laboratory were analyzed for iron, sulfate, total chlorine, copper, aluminum, nitrate, phosphorus, tannin-lignin, suspended solids, hardness, total chromium, and molybdenum using HACH DREL/2000 and HACH CEL/890 water test kits. A 100 ml sub-sample was preserved for ICP-AES analysis. Soil samples were collected from five of the seven ponds: BP6, BP7, BP9, BP13a and MM. Soil samples were collected on the north, south, east, and west sides of the pond 2 meters from the shoreline. Four additional sample points were placed midway between those sample points (northwest, southwest, southeast, northeast). A ninth soil sample was collected from the sediment at the center of the pond. Soil texture, color (wet and dry), structure, consistency, and moisture content were determined for each sample. Air dried samples were tested for pH, nitrate nitrogen, potassium, phosphorus, magnesium, calcium, ferric iron, sulfate, and aluminum. Five grams of soil was digested using EPA method 3050B for acid digestion of soils and the filtrate tested for molybdenum, copper, silver, chromium, iron, magnesium, aluminum, lead, cadmium, and potassium using an ICP-AES.

Results

Soil

Results of ICP-AES analysis of soil and water samples are given in fig. 3. The mean of the values of the four perimeter soil samples for each pond are given along with the values for the sediment and water samples taken at the center of each pond. In general, levels of the various elements were highest in the sediment sample, often several times that of the surrounding soil, and very low in the water samples. This is shown for the levels of aluminum, iron, magnesium, manganese, lead and potassium at PB6 in fig. 4. A two-tailed t-test revealed significant differences ($p<0.05$) between the mean values for chromium, aluminum, iron, and magnesium in the soil samples from the natural (BP6, BP9) versus the anthropogenic ponds (BP7, BP13a, MM). There are no significant differences between values for the water samples between the two types of ponds. The mean value for manganese in the sediments from the two natural ponds was significantly less than that for the anthropogenic ponds (two-tailed t-test, $p = 0.003$). Because of their limited sensitivity the results of the LaMotte soil tests were of limited value. When the anthropogenic ponds are compared to the two natural ponds, a two-tailed t-test reveals that there is a significant difference between the mean values for soil temperature (natural: 19.25°C, anthropogenic: 25.9°C; $p = 0.005$) and soil pH (natural: 5.04, anthropogenic: 5.96; $p = 0.016$) (fig. 5).

Water

Results of the field tests revealed that the mean values for temperature, pH, dissolved oxygen, and turbidity are all higher in the anthropogenic ponds (figs. 6, 7). Only the difference in pH proved to be statistically significant (two-tailed t-test, $p = 0.007$). Results of the Hach water tests for sulfate, nitrate, iron, phosphorus, total chlorine, magnesium, calcium, copper, tannin/lignin, total chromium, molybdenum, aluminum, and suspended solids are given in fig. 9. Values shown are the averages of the results for the five samples taken from each pond. When compared as groups (natural vs. anthropogenic) there are no consistent trends. The only difference between the ponds that proved statistically significant was for tannin-lignin content (natural: 4.64 ppm, anthropogenic: 1.12 ppm; $p = 0.036$) (fig. 8).

SAMPLE	Mo (ug/g)	Cu (ug/g)	Ag (ug/g)	Cr (ug/g)	Al (ug/g)	Fe (ug/g)	Mg (ug/g)	Mn (ug/g)	Pb (ug/g)	Cd (ug/g)	K (ug/g)
BP6 SOIL	3.220	25.732	7.261	12.221	4548.300	2131.700	399.920	145.710	38.578	0.506	369.400
BP6 SEDIMENT	0.000	11.208	3.210	30.968	26948.000	6788.000	1089.200	86.200	150.080	0.000	438.400
BP6 WATER	0.000	0.018	0.008	0.000	0.491	1.131	0.574	0.326	0.000	0.000	1.894
BP7 SOIL	0.000	44.328	0.000	22.231	8934.000	8924.000	892.200	104.050	73.059	0.000	126.090
BP7 SEDIMENT	5.800	195.040	0.000	87.680	22124.000	21760.000	2650.000	180.360	25.940	1.570	519.600
BP7 WATER	0.000	0.000	0.001	0.003	0.083	0.191	0.191	0.225	0.073	0.000	0.000
BP9 SOIL	5.015	6.591	1.907	4.966	2905.900	2007.900	139.547	66.110	63.594	1.288	129.811
BP9 SEDIMENT	0.000	0.000	0.000	14.708	2138.000	1119.600	85.000	62.480	111.080	0.000	86.160
BP9 WATER	0.000	0.000	0.000	0.001	0.320	1.004	0.312	0.107	0.000	0.000	0.817
BP13a SOIL	0.000	7.841	0.000	13.801	6696.000	8346.000	741.400	109.840	84.630	0.280	199.890
BP13a SEDIMENT	11.752	24.776	0.000	36.092	21116.000	20448.000	2242.000	169.600	258.040	0.000	603.200
BP13a WATER	0.000	0.000	0.001	0.009	0.963	3.659	0.683	0.265	0.198	0.000	1.042
MM SOIL	0.000	17.985	0.750	20.115	7285.333	9606.667	698.800	133.707	22.080	0.252	198.693
MM SEDIMENT	0.000	15.620	13.644	0.000	5796.000	8708.000	673.200	193.120	0.000	3.524	257.320
MM WATER	0.000	0.003	0.000	0.000	0.198	0.167	1.649	0.247	0.000	0.005	0.957
BP1 WATER	0.000	0.000	0.000	0.000	0.258	0.292	0.342	0.264	0.162	0.000	0.787
BP2 WATER	0.000	0.016	0.000	0.024	0.273	0.440	0.357	0.287	0.125	0.000	0.453

Fig 3. ICP-AES results for soil, sediment and water

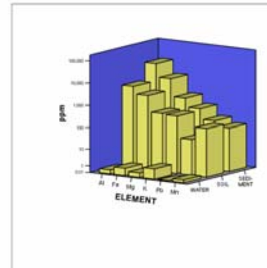

Fig 4. BP6 soil, sediment & water

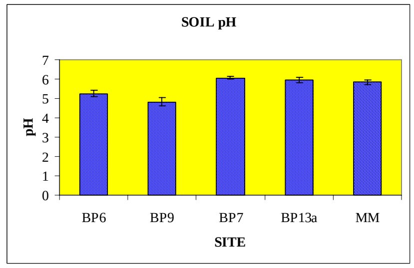

Fig 5.

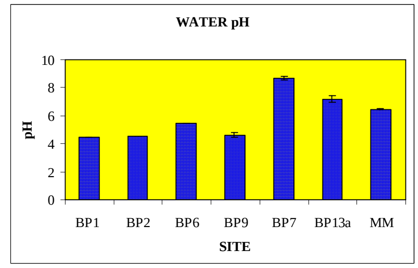

Fig 6.

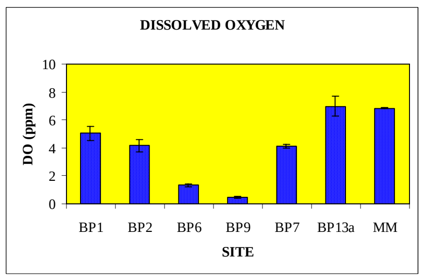

Fig 7

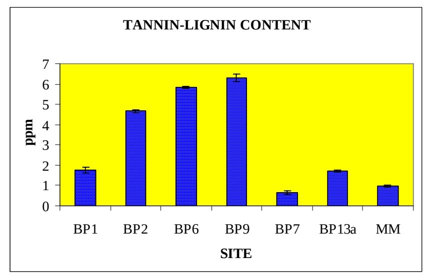

Fig 8

SITE	Sulfate	Nitrate	Fe	P	Total Cl	Hardness: Mg	Hardness: Ca	Copper	Tannin-Lignin	Total Cr	Mo	Al	Suspended Solids
BP1	0.2	0.2	0.386	0.142	0.02	1.366	1.118	0.066	1.76	0.002	0.18	0.088	56.4
BP2	1.6	0.02	0.374	0	0.028	1.376	0.916	0.01	4.66	0.1	0	0.11	52.4
BP6	0.275	0.06	0.49	0.2	0.024	1.806	1.724	0.014	5.84	0	0	0.086	30.4
BP9	0	0.28	0.902	0.236	0.044	1.076	1.456	0.024	6.3	0	0	0.1	51.2
BP7	0.4	0.08	0.55	0.154	0.012	3.88	0.798	0.022	0.66	0.028	0.08	0	33.2
MM	1	0.04	0.248	0.222	0.032	3.446	0	0.046	0.98	0.014	0.14	0.018	22.6
BP13a	0.2	0	2.568	0.246	0.048	1.832	1.364	0.058	1.72	0.004	NA	0.52	60.2

Fig 9.

Discussion

Coastal plain ponds are an important element of the natural history of Long Island. These wetlands serve important ecosystem functions and support populations of a significant number of rare species, both plant and animal [10]. Many coastal plain ponds have been altered or lost due to development [11]. Wetland restoration and creation are attempts to mitigate the effects of such losses. Within the boundaries of BNL there are a number of coastal plain ponds, both naturally occurring and anthropogenic. These ponds represent a significant portion of the known breeding habitat for tiger salamanders (*Ambystoma tigrinum*) in New York. A primary goal of wetland restoration and creation is to produce habitat that is functionally equivalent to naturally occurring elements [11]. Our study reveals that there are identifiable differences between natural and anthropogenic ponds on BNL with respect to soil and water chemistry. It is proposed that many of these differences are related to the absence of a tree canopy and woody shrubs around the anthropogenic ponds. The absence of a surrounding tree canopy exposes the anthropogenic ponds to greater levels of solar radiation, raising both soil and water temperature. The presence of trees and shrubs around the natural ponds contributes significant amounts of leaf litter to the ponds and soil, increasing tannin-lignin content and lowering the pH. Though these differences exist between natural and anthropogenic ponds, they might not have an effect on breeding site selection by tiger salamanders (*Ambystoma tigrinum*), since tiger salamanders are known to use both natural and anthropogenic coastal plain ponds on BNL [12],

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